Prepared in cooperation with the State of Hawaii Department of Transportation

Rainfall, Streamflow, and Water-Quality Data During Stormwater Monitoring, Halawa Stream Drainage Basin, Oahu, Hawaii, July 1, 2005 to June 30, 2006

Open-File Report 2006-1223

U.S. Department of the Interior
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Dirk Kempthorne, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

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Conversion Factors, Datums, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Discharge	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/sec)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced relative to mean sea level.

Horizontal coordinate information is referenced to Old Hawaiian Datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (μg/L).

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Rainfall, Streamflow, and Water-Quality Data During Stormwater Monitoring, Halawa Stream Drainage Basin, Oahu, Hawaii, July 1, 2005 to June 30, 2006

By Todd K. Presley, Marcael T.J. Jamison, and Stacie T.M. Young-Smith

Abstract

Storm runoff water-quality samples were collected as part of the State of Hawaii Department of Transportation Stormwater Monitoring Program. This program is designed to assess the effects of highway runoff and urban runoff on Halawa Stream. For this program, rainfall data were collected at two stations, continuous discharge data at one station, continuous streamflow data at two stations, and water-quality data at five stations, which include the continuous discharge and streamflow stations. This report summarizes rainfall, discharge, streamflow, and water-quality data collected between July 1, 2005 and June 30, 2006.

A total of 23 samples was collected over five storms during July 1, 2005 to June 30, 2006. The goal was to collect grab samples nearly simultaneously at all five stations, and flow-weighted time-composite samples at the three stations equipped with automatic samplers; however, all five storms were partially sampled owing to lack of flow at the time of sampling at some sites, or because some samples collected by the automatic sampler did not represent water from the storm.

Samples were analyzed for total suspended solids, total dissolved solids, nutrients, chemical oxygen demand, and selected trace metals (cadmium, chromium, copper, lead, nickel, and zinc). Additionally, grab samples were analyzed for oil and grease, total petroleum hydrocarbons, fecal coliform, and biological oxygen demand. Quality-assurance/quality-control samples were also collected during storms and during routine maintenance to verify analytical procedures and check the effectiveness of equipment-cleaning procedures.

Introduction

The State of Hawaii Department of Transportation (DOT) Stormwater Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2005) was implemented on January 1, 2001 to monitor the Halawa Stream drainage basin, Oahu, Hawaii. The Stormwater Monitoring Program Plan was designed to fulfill part of the permit requirements for the National Pollutant Discharge Elimination System program and is revised yearly. The Stormwater Monitoring Program Plan requires the collection of rainfall, streamflow, and water-quality data at selected stations in the Halawa Stream drainage basin.

This report presents rainfall and streamflow data collected from July 1, 2005 to June 30, 2006, summarizes water-quality data, and describes sampling techniques. Five storms were sampled during the period of July 1, 2005 to June 30, 2006. Twenty-three samples were collected during these five storms. In addition, five quality-assurance/quality-control (QA/QC) samples were collected: three samples were collected concurrently with storm samples and two samples were collected between storms after routine cleaning of the sampling equipment. Water-quality data for the QA/QC samples are not published in this report nor at the USGS website, but are available upon request from the USGS Pacific Islands Water Science Center in Honolulu, Hawaii.

Data-Collection Network

Stream-stage, stream-discharge, rainfall, and water-quality data were collected at selected stations in the Halawa Stream drainage basin (fig. 1). Rainfall data were collected at two stations, 212428157511201, North Halawa Valley rain gage at H-3 tunnel portal (abbreviated to Tunnel rain gage) and 212304157542201, North Halawa rain gage near Honolulu (abbreviated to Xeriscape garden rain gage). Rainfall data have been collected at the Tunnel and Xeriscape garden rain gages since July 1998 and May 1983, respectively.

Discharge data were collected at 212353157533001, Storm drain C. Streamflow data were collected at two stations in North Halawa Valley: 16226200, North Halawa Stream near Honolulu (abbreviated to Xeriscape garden), and 16226400, North Halawa Stream at Quarantine Station (abbreviated to Quarantine station). Discharge data have been collected at Storm drain C since September 1998, and streamflow data have been collected at Xeriscape garden and Quarantine station since February 1983 and October 2001, respectively. The gage at the Quarantine station site was destroyed on December 7, 2003 and rebuilt in June 2005. Data collection at Quarantine station resumed on October 1, 2005. Storm drain C, Xeriscape garden, and Quarantine station are equipped with automatic samplers.

Rainfall and streamflow data were collected using variable sampling intervals depending on rainfall or streamflow rates. Data from the two rain gages, the two streamflow-gaging stations, and Storm drain C are transferred daily to the USGS National Water Information System (NWIS) database using cellular-phone and satellite telemetry. Recent data can be viewed at *http://hi.water.usgs.gov/* under the “Real-Time Stations” by selecting “Streamflow” or “Rainfall”, and then selecting the appropriate USGS station numbers. Historic rainfall and streamflow data can be accessed through the website *http://waterdata.usgs.gov/hi/nwis/sw* under the “Daily Data” link.

Water-quality data were collected at five stations (fig. 1): 212356157531801, North Halawa Stream at Bridge 8 near Halawa (abbreviated to Bridge 8); Storm drain C; Xeriscape garden; Quarantine station; and 16227100, Halawa Stream below H-1 (abbreviated to Stadium). The Bridge 8 station is about 0.75 mile (mi) upstream from the discharge point of Storm drain C on North Halawa Stream. Storm drain C collects runoff from an approximately 4-mi length of freeway starting at the leeward tunnel portal and extending to mid-valley, and discharges directly to North Halawa Stream (fig. 1). The Xeriscape garden station is directly upstream from a light-industrial area near North Halawa Stream, and about 0.75 mi downstream of the discharge point of Storm drain C. The Quarantine station is about 1 mi downstream of Xeriscape garden and near the downstream end of the light-industrial area that borders the North Halawa Stream. The Stadium station is about 1.5 mi downstream of the Quarantine station, downstream from the confluence of North and South Halawa Streams, downstream from the crossing of H-1 freeway, and directly upstream from the mouth at Pearl Harbor. Water-quality data have been previously collected at Storm drain C (1998-present), Xeriscape garden (1983-present), and Stadium (1988-present) by the USGS as part of the H-3 freeway construction monitoring study (Wong, 2005; Wong and Young, 2001) and can be viewed at *http://waterdata.usgs.gov/hi/nwis/qwdata* by selecting the appropriate USGS station numbers.

Water-Quality Sampling Techniques

Water-quality samples include grab samples collected manually, grab samples collected by an automatic sampler, and flow-weighted time-composite samples collected by an automatic sampler. Each grab and composite sample is assigned a mean sampling time based on the start and finish time of the grab sampling process, or the times of collection of the sample bottles used for the grab or composite sample from the automatic sampler.

Sampling Requirements

The DOT Stormwater Monitoring Program Plan states that water-quality samples will be collected at least once per quarter during periods of storm runoff from each of the five water-quality monitoring stations (fig. 1). The plan also states that efforts will be made to sample all five water-quality monitoring stations during the same storm, and if a storm does not occur during a quarter, no samples will be collected.

A complete set of samples for a storm consists of five grab samples (one from each of the five stations), three flow-weighted time-composite samples (one each from Storm drain C, Xeriscape garden, and Quarantine station), and one QA/QC sample. However, some storms are brief and do not produce adequate runoff to sample all five stations and collect all samples. In practice, these storms have been sampled as thoroughly as possible and analyzed for as many constituents as practical.

Storm Criteria

The U.S. Environmental Protection Agency’s (USEPA) Storm Water Sampling Guidance Manual (U.S. Environmental Protection Agency, Office of Water, 1993) provides guidelines for stormwater sampling. Two primary criteria are provided in these guidelines, although one of the criteria is not always met. The first criterion requires at least 0.1 inch (in.) of accumulated rainfall. Historically, rainfall accumulations have exceeded 0.1 in. at the Tunnel rain gage and Xeriscape garden rain gage when stormwater sampling was conducted. The second criterion requires that samples be collected only for storms preceded by at least 72 hours of dry weather. The second criterion would prevent sampling of most storms on North Halawa Stream because the Halawa Stream drainage basin, as well as many other parts of Oahu, receives tradewind showers almost daily.

In practice, criteria used to initiate sampling of the stream and storm drain were based on the rate of rainfall accumulation and the rise of stage in Storm drain C, Xeriscape garden and Quarantine station gaging stations. Each automatic sampler is triggered at predetermined station-specific stream-stage thresholds. The automatic samplers at Storm drain C, Xeriscape garden, and Quarantine station collect samples at stages that correspond to discharges greater than 3.1, 40.1, and 47.0 cubic feet per second (ft^3/s), respectively.

Sample Collection

Grab samples were collected manually using isokinetic, depth-integrating samplers and equal-width increment (EWI) sampling techniques (Wilde and others, 1998). Samplers are

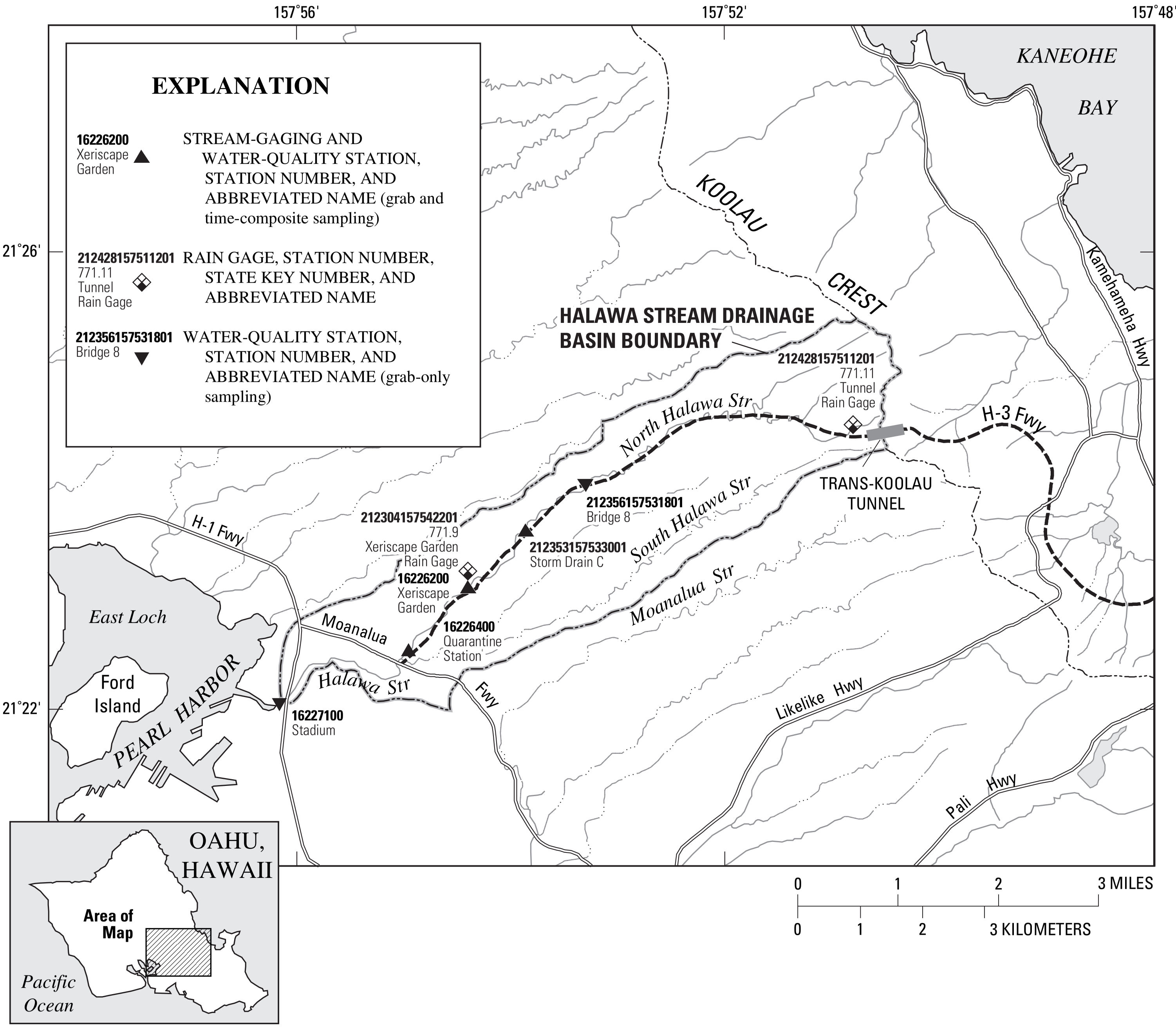

Figure 1. Stream-gaging stations, rain gages, and water-quality sampling stations in the Halawa drainage basin, Oahu, Hawaii.

made of high-density polyethylene (HDPE) and collect water in an “isokinetic” manner, in which water enters the sampler at the same velocity as the stream at the sampling point. The EWI sampling technique utilizes evenly spaced sampling increments along the cross section of the stream. The volume of sample collected at each increment is proportional to the discharge at that increment. Samples collected at each increment are combined in a HDPE churn.

An EWI sample is practical when depths are greater than 0.5 feet (ft) and the stream is wadeable. During high-discharge storms, streams are not waded for safety reasons. However, at each station, the stream appears to be sufficiently well mixed during high-discharge storms, therefore the EWI method is not always necessary. During high-discharge storms, the grab sample may have been collected with the isokinetic sampler along a single vertical station at the estimated centroid of flow within the cross section of the stream. Sub-samples from the single-vertical technique are then combined in a HDPE churn.

A flow-weighted, time-composite sample is created by combining, in a HDPE churn, all or part of the samples collected by the automatic samplers. The desired volume of water from each sample is proportional to the stream-discharge volume between sample-collection times. Composite samples were collected over time periods that sometimes lasted several hours.

Automatic samplers collect water from a fixed point in the stream channel after pre-determined stage thresholds are met. The automatic samplers have a capacity of 24, 1-liter bottles. When the first threshold has been met, the automatic samplers are programmed to collect water samples every two minutes for the first five samples, and then every 15 minutes for the remaining 19 samples. The first stage thresholds for the samplers correspond to discharges of 3.1, 40.1, and 47.0 ft^3/s for Storm drain C, Xeriscape garden, and Quarantine station gaging stations, respectively. In order to collect enough water in each sample during storms with quickly rising and falling stream stages, or greater overall flow, a second set of stage thresholds, corresponding to higher discharges, is used to trigger the samplers to sample every 7 minutes. These higher stage thresholds correspond to discharges of 16.1, 90.0 and 108 ft^3/s for Storm drain C, Xeriscape garden, and Quarantine station gaging stations, respectively.

The first five samples collected every two minutes by the automatic sampler were sometimes combined and analyzed as a grab sample when grab samples could not be collected manually. The first three of these five samples were collected in teflon bags and were used for oil and grease (O+G) and total petroleum hydrocarbon (TPH) analyses. The fourth and fifth samples, collected in low-density polyethylene (LDPE) bags, were then used for the remaining analyses.

The main limitation associated with using samples from the automatic sampler to replace grab samples is that some constituents require the sample to be chilled prior to analysis and analyzed within a certain “holding time” after collection. The automatic samplers are not equipped with refrigeration units, and thus maximum holding times for selected constituents can be exceeded. Additionally, the automatic samplers can decrease the concentration of constituents if the constituent bonds to the teflon tubing of the intake line and the silicon tubing of the peristaltic pump. Nutrient analyses would be the most susceptible to holding time and refrigeration problems, whereas O+G and TPH analyses are the most susceptible to problems associated with the constituent bonding to tubing.

Some storms are difficult to sample due to the timing and distribution of discharge. Situations in which the storm samples deviated from the sampling requirements outlined in the sampling plan occurred when there were multiple peaks in discharge, if stream discharge had decreased too much after a storm to collect a grab sample, or if a small peak in discharge was followed by a much larger peak discharge. In these cases, deviation from the sampling requirements include: (1) one or more grab samples will be made from the samples collected by the automatic sampler, or (2) a composite sample will be made from fewer than 24 samples if a gap of a few or more hours elapse between the times at which the samples from the automatic sampler were collected.

Determination of Discharge

At the Bridge 8, Storm drain C, Xeriscape garden, and Quarantine stations, discharge associated with each sample was determined using a streamflow rating created for the station, or by direct measurement using a current meter. Streamflow ratings were developed using measurements and results from hydraulic models that were verified by measurements. At the Stadium station, the wide and curving concrete-lined channel and shallow and swift streamflow preclude development of an accurate streamflow rating. When possible, discharge at this station was measured using a current meter. At higher flows, discharge was measured either by using float-measurement techniques or a radar gun. The float-measurement technique involves measuring the time it takes a float to travel over a known distance to determine water velocity. The radar gun measures surface velocity at multiple points in the cross section. In both techniques, the area of the cross section was estimated using measured water depths and surveyed dimensions of the channel. USGS practices for making discharge measurements and streamflow ratings are summarized by Rantz and others (1982).

An average-discharge value was calculated for each composite sample. The average-discharge value is equal to the total volume of water that flowed by the gaging station during sample collection, divided by the total elapsed time between the first and last the samples collected by the autosampler. To determine the volume of water associated with each individual sample, the discharge at the time of sample collection was multiplied by the elapsed time. The elapsed time for each sample, excluding the first and last samples, is computed by taking the difference between the times associated with samples taken before and after the sample and dividing by two. To compute the elapsed time of the first and last samples, the difference between the time of the sample and next/previous sample is divided by two. Volumes determined for each sample were summed, and the total volume was divided by the sum of all the time increments.

All discharge values are reported to appropriate numbers of significant figures. These discharge values and the corresponding values of constituent concentration are used to compute loads. Discharge-value reporting and the calculation of loads are discussed in appendix A.

Sample Processing, Analysis, and Quality Assurance/Quality Control

USGS water-quality sampling methods (Wilde and others, 1998) were followed to prevent possible contamination during sample processing. Both grab and composite samples were processed using churns to mix and suspend sediment while delivering the sample to specific bottles for the various constituent analyses.

As required by the DOT Stormwater Sampling Program Plan, field measurements of temperature, pH, and specific conductance were made for grab samples. Each composite and grab sample was analyzed for total suspended solids (TSS), total dissolved solids (TDS), nutrients, chemical oxygen demand (COD), and selected trace metals (cadmium, chromium, copper, lead, nickel, and zinc). Each grab sample was also analyzed for O+G, TPH, fecal coliform (FC), and biological oxygen demand (BOD). The minimum reporting levels for each of the analyzed properties and constituents (table 1) are based on values published by the USGS National Water Quality Laboratory (NWQL). Calculated values (organic nitrogen and total nitrogen) do not have minimum reporting levels. More information about minimum reporting levels and how

Table 1. Minimum reporting levels of properties and constituents for all samples collected from Halawa Stream drainage basin from July 1, 2005 to June 30, 2006, Oahu, Hawaii.

[std., standard; µS/cm, microsiemens per centimeter at 25ºC; mg/L, milligrams per liter; ºC, degrees Celsius; µg/L, micrograms per liter; --, no minimum reporting level, computed value; MPN/100mL, most probable number (of colonies) per 100 milliliters]

Property or constituent	Minimum reporting levels
pH	0.1 std. units
Specific conductance	2.6 µS/cm
Temperature	0.5oC
Total suspended solids	10 mg/L
Total dissolved solids	10 mg/L
Total nitrogen[a]	--
Organic nitrogen[b]	--
Ammonia, dissolved[c]	0.010 mg/L
Nitrogen, total organic + ammonia (Kjeldahl)	0.10 mg/L
Nitrogen, nitrite + nitrate, dissolved	0.060 mg/L
Phosphorus, dissolved	0.04 mg/L
Total phosphorus	0.040 mg/L
Chemical oxygen demand	10 mg/L
Total cadmium	0.04 µg/L
Total chromium	2 µg/L
Total copper	0.6 µg/L
Total lead	0.06 µg/L
Total nickel	0.16 µg/L
Total zinc	2 µg/L
Oil and grease	7 mg/L
Total petroleum hydrocarbons	2 mg/L
Biological oxygen demand	1 mg/L
Fecal coliform	2 MPN/100mL

[a]Total nitrogen is calculated by adding nitrogen, total organic+ammonia (Kjeldahl) to nitrogen, nitrite+nitrate, dissolved.

[b]Organic nitrogen is calculated by subtracting ammonia, dissolved from nitrogen, total organic+ammonia (Kjeldahl).

[c]Ammonia, dissolved is reported as nitrogen.

they are determined by NWQL can be found in Childress and others (1999).

FC and BOD analyses were performed by Aecos Incorporated, a private laboratory on Oahu. Aecos Incorporated follows their own quality assurance/quality control procedures; any inquiries about their methods should be directed to their laboratory. Storms that occurred on weekends or holidays were not sampled for FC or BOD; Aecos Incorporated is closed on these days, therefore maximum holding times for FC and BOD samples would be exceeded if they were analyzed on the subsequent work day.

All other analyses were performed at the USGS NWQL, in Denver, Colorado. The methods used for analyses of all water-quality constituents and quality-control practices at NWQL are documented in Friedman and Erdmann (1982), Fishman and Friedman (1989), Pritt and Raese (1992), Patton and Truitt (1992), and Fishman (1993).

A field or laboratory duplicate sample is required by the Stormwater Sampling Program Plan for each storm sample. A field duplicate is a sample that is collected concurrently with a grab sample and the analytical results are used to verify the sampling method. A laboratory duplicate is a sample that is split into two equal parts during sample processing and the results are used to verify the laboratory methods. Field duplicate QA/QC samples were collected at the Quarantine station sites during the July 12, 2005 and the February 28—March 2, 2006 storms, and at Bridge 8 during the May 5, 2006 storm. A laboratory duplicate also was collected at the Quarantine station site on July 12, 2005. No QA/QC samples were collected during the January 22—23 storm due to low sample volumes from the automatic sampler at Xeriscape garden, nor during the February 19—20 storm due to the timing of the storm and lack of flow at all of the sites during sampling.

During the period between storms, non-dedicated and non-disposable equipment, such as churns, isokinetic samplers, automatic-sampler-intake lines, and teflon automatic-sampler bottle liners, were cleaned following procedures in Wilde and others (1998). Field-blank samples were collected on December 29, 2005 and May 17, 2006. Inorganic blank water (IBW), free of inorganic constituents, was passed through the automatic sampler and collected. The IBW field-blank samples were analyzed for the same inorganic constituents as the storm samples.

Rainfall and Streamflow Data

Data presented in this report are provisional and subject to revision. Hydrographs of daily rainfall and daily mean streamflow for the period of July 1, 2005 through June 30, 2006 are shown in figure 2. A total of 60.1 in. of rain was recorded at Xeriscape garden rain gage during this period.

At the Tunnel raingage, however, the collection can overflowed during September 14 to September 30, 2005, and the recorder malfunctioned due to low battery voltage during October 13 to November 9, 2005, March 18 to 22, 2006, and May 8 to 23, 2006. Since the Tunnel raingage has missing record, an annual total cannot be calculated for this station.

The highest recorded daily rainfall at the Tunnel rain gage was 10.6 in. on April 2, 2006. The highest recorded daily rainfall at the Xeriscape garden rain gage was 3.3 in. on October 1, 2006. The minimum daily rainfall that resulted in sufficient runoff for the collection of storm samples was 1.6 in. at the Tunnel rain gage and 0.3 in. at the Xeriscape garden rain gage on February 19, 2006. Other sampling days may have had less rainfall, however, these days were preceded by days of greater rainfall.

Periods of high discharge in North Halawa Stream occurred during early October 2005 and late March to early April 2006. At Xeriscape garden, the two highest daily mean discharges for the year were 170 ft^3/s on October 1, 2005, and 162 ft^3/s on April 2, 2006. Data collection resumed at the Quarantine station gage on October 1, 2005, therefore, no data were collected between July 1 and September 30, 2005. At the Quarantine station , the two highest recorded daily mean discharges for the year were 141 ft^3/s on October 1, 2005, and 168 ft^3/s on April 2, 2006.

Halawa Stream has intermittent flow. The longest period with zero daily mean discharge during the year was between August 27 and September 2, 2005 at the Xeriscape garden gage, and between December 7, 2005 and January 19, 2006 at the Quarantine station gage during the period of available record.

For Storm drain C, the highest daily mean discharges were on the same days as the highest discharges in the stream. The two highest daily mean discharges were 3.2 ft^3/s on October 1, 2005, and 4.9 ft^3/s on April 2, 2006. The longest period with zero daily mean discharge at this station was between December 13 and 31, 2005.

Stormwater Sampling: Conditions and Results

During the period July 1, 2005 through June 30, 2006, at least 20 storms occurred with sufficient runoff to trigger the automatic samplers at the predetermined thresholds at Xeriscape garden and Quarantine station, and at least 50 periods of rainfall occurrred that resulted in sufficient discharge that would have triggered the Storm drain C automatic sampler. Of these storms, five were sampled: July 12, 2005, January 22—23, February 19—20, February 28—March 2, and May 5, 2006. Discharge, temperature, field or laboratory measured pH and specific-conductance values, constituent concentrations, and average loads for the grab and composite samples are shown in appendix B. Water-quality data presented in this report are provisional and subject to revision.

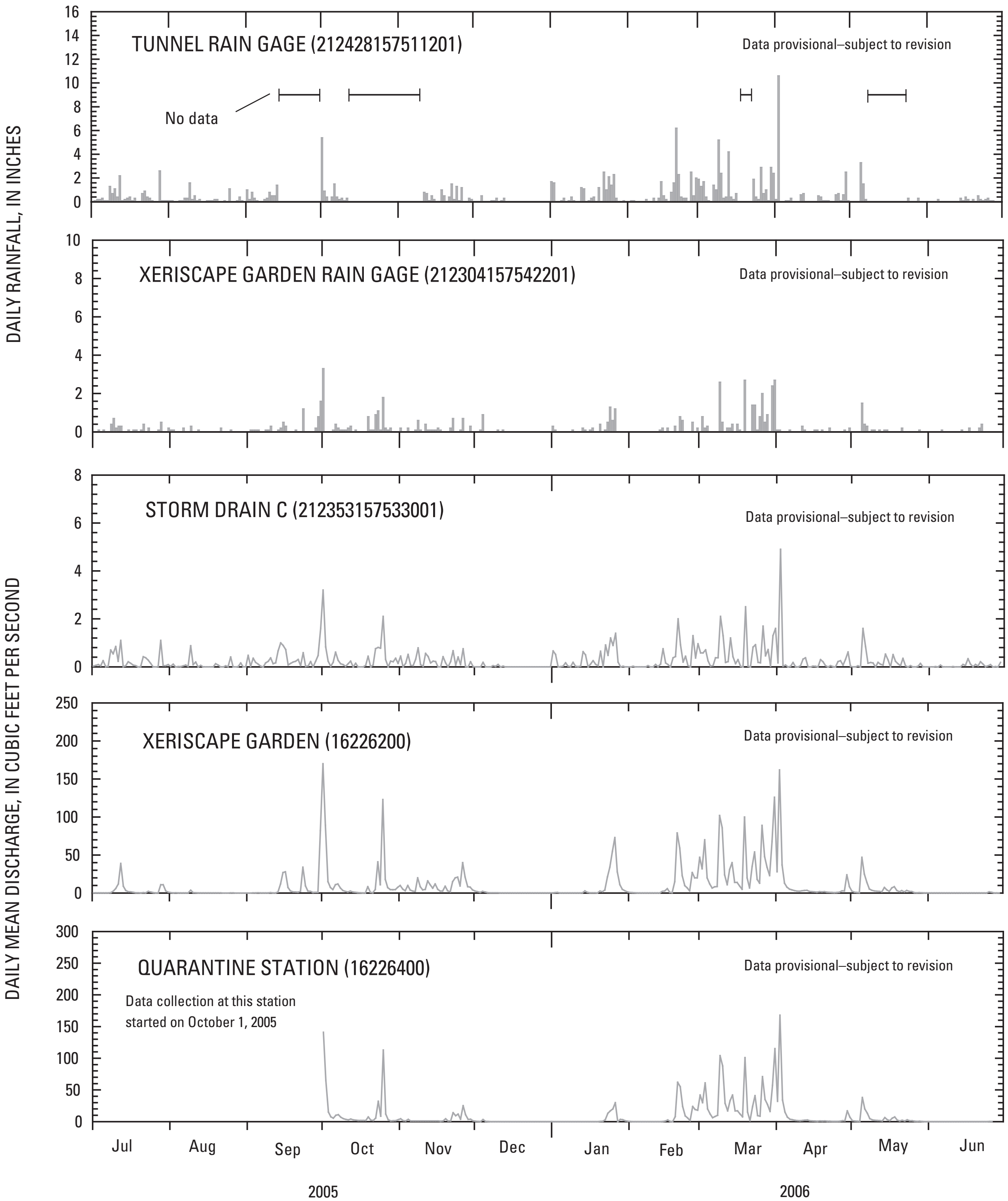

Figure 2. Rainfall and discharge for stations within the Halawa Stream drainage basin, Oahu, Hawaii, for July 1, 2005 to June 30, 2006.

Third Quarter 2005 – July 1 to September 30, 2005

One storm, on July 12, 2005, was sampled during the third quarter 2005.

Storm of July 12, 2005

A total of 2.6 in. of rain fell during July 11 and 12 at the Tunnel rain gage, resulting in enough runoff for a storm sample, collected on July 12, 2005. Hydrographs of discharge at Storm drain C and Xeriscape garden during July 1 to September 30, 2005 are shown in figure 3 and 4 (the Quarantine station gage was not operational at the time).

Composite samples were collected from Storm drain C and Xeriscape garden gages. Manual grab samples were collected from all stations except for Storm drain C; there was not enough flow in the storm drain at the time of sampling. Beginning and ending composite sample-collection times are displayed on the hydrographs in figures 3 and 4. Samples were analyzed for all constituents listed in the Stormwater Monitoring Program Plan except for FC and BOD (State of Hawaii Department of Transportation Highways Division, 2005).

Bridge 8.--The grab sample was collected using the EWI method. The stream channel was about 17 ft wide, and was sampled at 10 sampling points distributed every 1.5 ft. A discharge of 45.8 ft^3/s was measured about 30 minutes prior to sampling using a current meter.

The cooler that contained this sample did not arrive at the NWQL in time, thus holding times were exceeded for the analyses of nutrients, oil and grease, and total petroleum hydrocarbons. Only the analyses for metals were conducted.

Storm drain C.--No grab sample was collected since there was insufficient discharge in the storm drain at the time of sampling. The peak discharge was 24 ft^3/s at 08:34 on July 12, 2005.

The automatic sampler filled a total of six bottles over a two-hour period. The hydrograph during the sampling shows that several small peaks occurred during the storm. The volume of water collected from the sampler was not enough to make a flow-weighted composite sample, thus the entire contents of the six bottles were combined to make a non-flow-weighted composite sample. The average discharge for the composite sample was 7.3 ft^3/s.

The cooler that contained this sample did not arrive at the NWQL in time, thus holding times were exceeded for the analyses of nutrients, oil and grease, and total petroleum hydrocarbons. Only the analyses for metals were conducted.

Xeriscape garden.-- The grab sample was collected using the EWI method about 20 ft upstream from the gage. The stream was about 27 ft wide, and was sampled at 9 sampling points distributed every 2.7 ft. A discharge of 40 ft^3/s was determined by noting the stage at the time of sampling and using the rating for the gage. Peak discharge for the storm was 211 ft^3/s at 09:25 on July 12, 2005.

A flow-weighted composite sample was created by combining 11 samples from the automatic sampler. Although the sampler was triggered during the rising stage, malfunctions of the pump or blockage of the sampling orifice prevented the filling of bottles during the early part of the storm. Samples used were collected after the peak discharge. The average discharge for the composite sample was 99 ft^3/s.

Quarantine station.--A grab sample was collected using the EWI method. The stream was 16.8 ft wide, and was sampled at 10 sampling points distributed every 1.5 ft. A field duplicate was also collected at this site. The NWQL also analyzed a laboratory duplicate. A stream discharge of 35.7 ft^3/s was measured concurrently with sampling using a USGS current meter.

Stadium.--A grab sample was collected using the EWI method. The stream was 60 ft wide, and was sampled from 5 sampling points distributed every 10 ft. A stream discharge of 93.8 ft^3/s was measured concurrently with sampling using a USGS current meter.

Fourth Quarter 2005 – October 1 to December 31, 2005

Hydrographs showing discharge during the fourth quarter 2005 for Storm drain C, Xeriscape garden, and Quarantine station gages are shown in Figure 5.

No storms were sampled during this quarter. The first storm, which began on September 30, 2005, had peak discharges that exceeded 1,000 ft^3/s at Xeriscape garden and Quarantine station gages on October 1, 2005 (fig.5). Other operational duties and scheduling prevented USGS personnel from sampling this storm.

A brief storm occurred on October 24—25, 2005. There was a small peak in discharge two days prior to the storm. The hydrograph shows the peak discharge occurred at about 01:30 on October 25, and subsequently, discharge dropped rapidly. Discharges were too low to sample by the time the sampling teams could be mobilized.

First Quarter 2006 – January 1 to March 31, 2006

Three storms were sampled during the first quarter of 2006. The first two storms, January 22—23 and February 19—20, were partially sampled due to the field and flow conditions. The third storm on February 28—March 2 was completely sampled with the exception of the grab sample at the Storm drain C.

Storm of January 22—23, 2006

The storm on January 22—23, 2006 produced insufficient runoff to allow sampling at all stations. As a result, only a composite sample from Xeriscape garden was collected. Dis-

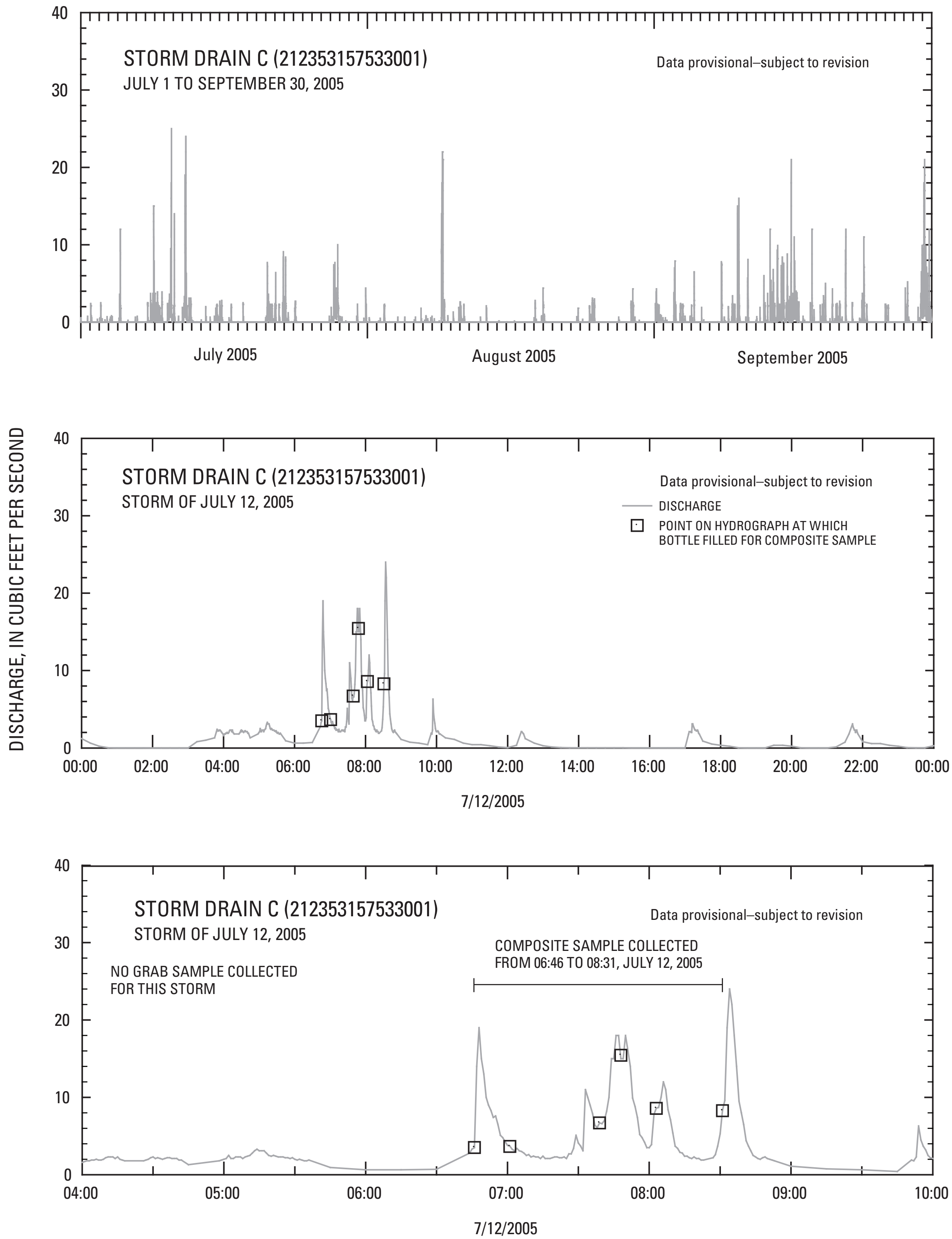

Figure 3. Discharge at Storm drain C (212353157533001) for July 1 to September 30, 2005; detail of July 12, 2005; and detail of the 6-hour period from 04:00 to 10:00 on July 12, 2005, Oahu, Hawaii.

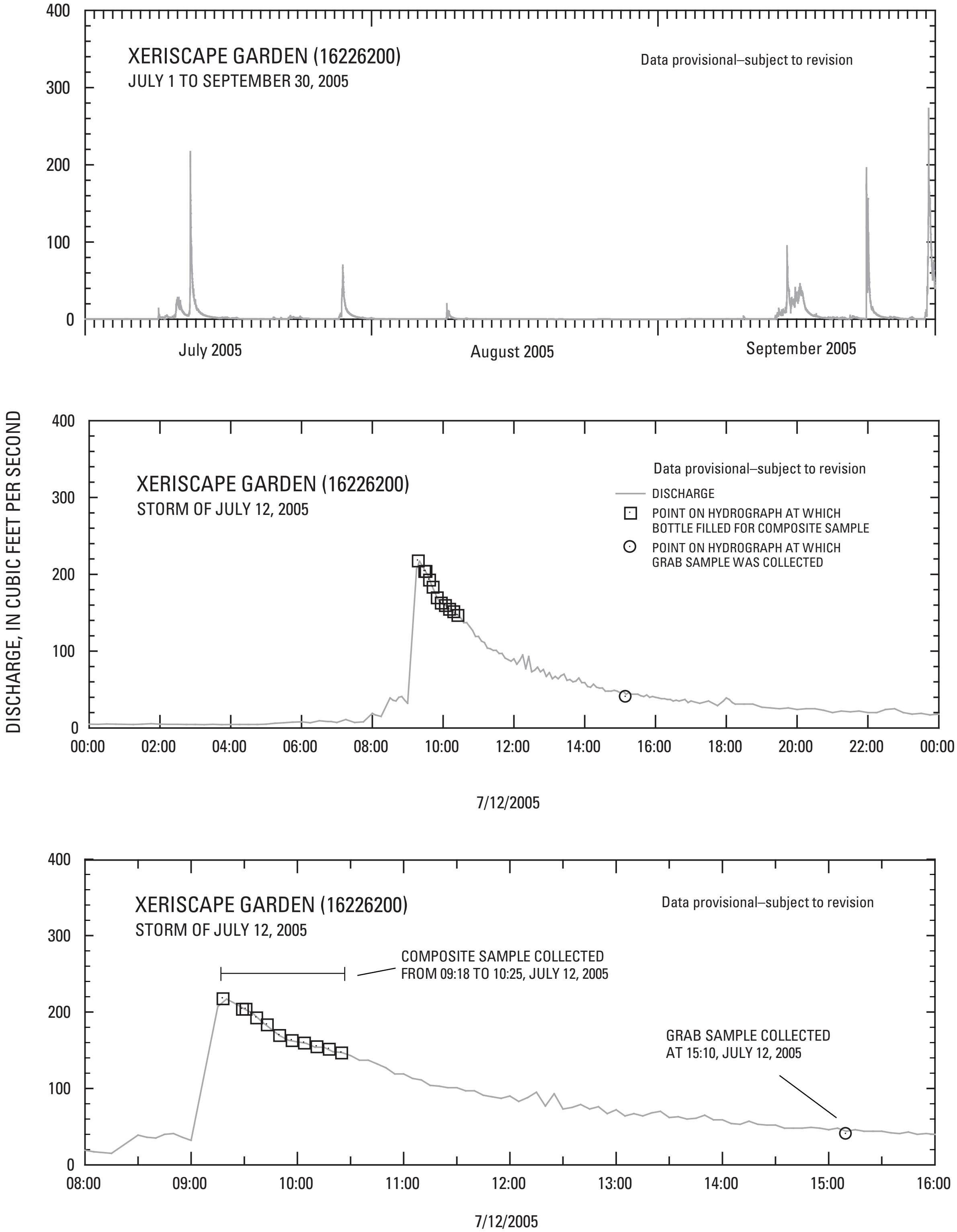

Figure 4. Stream discharge at Xeriscape garden (16226200) for July 1 to September 30, 2005, detail of July 12, 2005, and detail of 8-hour period from 08:00 to 16:00 on July 12, 2005, Oahu, Hawaii.

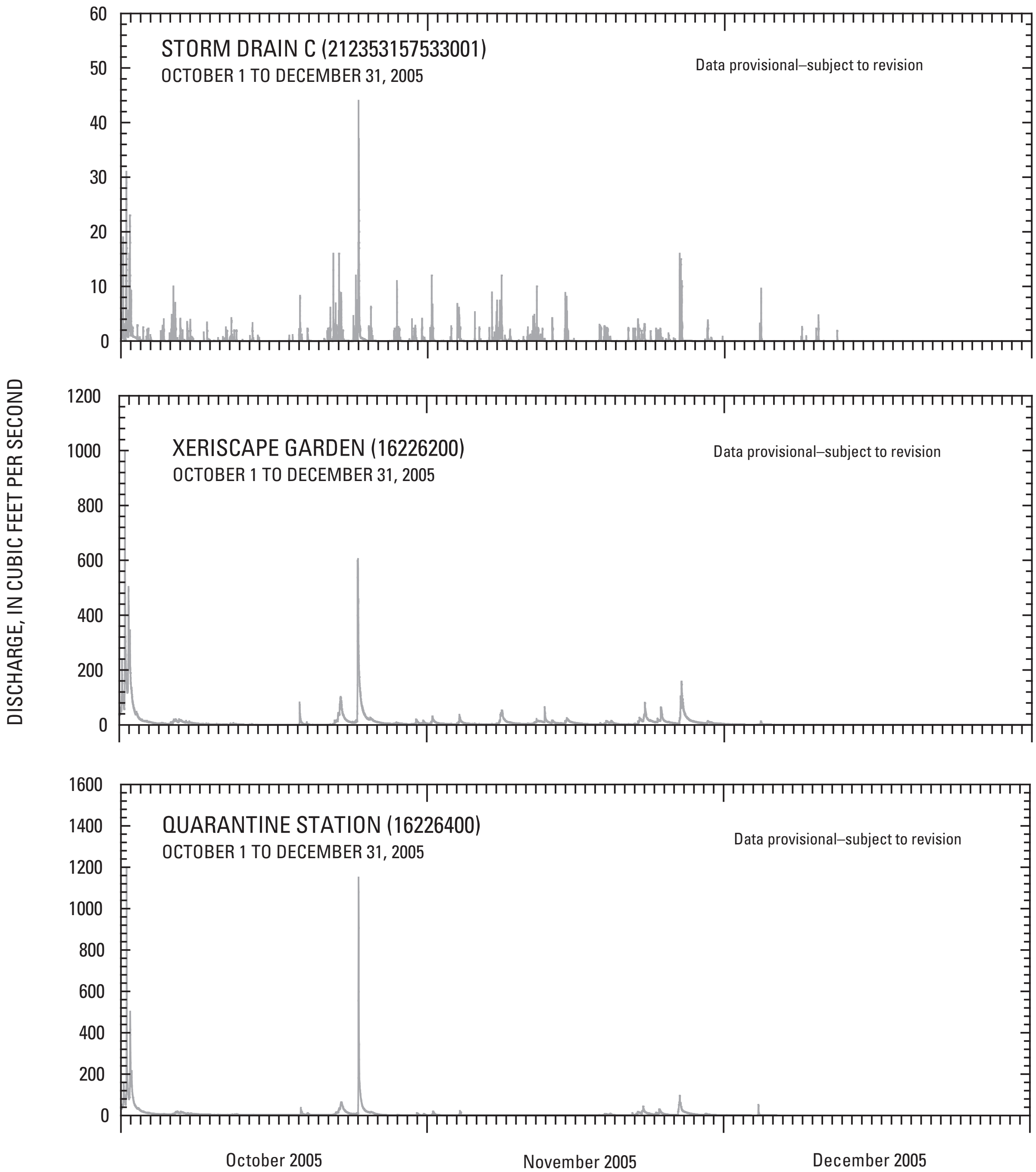

Figure 5. Discharge at Storm drain C (212353157533001), and stream discharge at Xeriscape garden (16226200) and Quarantine station (16226400) for October 1 to December 31, 2005, Oahu, Hawaii.

charge for Storm drain C, Xeriscape garden, and Quarantine station are shown in figures 6, 7 and 8, respectively.

Xeriscape garden.--A composite sample was collected between 01:50 to 04:00 on January 23, 2006. The composite sample was created using water from 11 of the 12 bottles that were filled. The average discharge for the composite sample of 44 ft^3/s was determined using the stage data at the time each sample bottle was filled and the streamflow rating from this gage. The peak discharge for this storm was 48 ft^3/s at 02:05 on January 23, 2006.

Storm of February 19—20, 2006

Only three samples were collected during this storm: a grab sample and a composite sample, both from the automatic sampler, at Xeriscape garden, and a composite sample from Quarantine station. The discharge at Storm drain C rose and fell too quickly to take a grab or composite sample. The peak of the storm occurred in the afternoon, therefore sampling crews were unable to collect grab samples from the five sites before sunset. Hydrographs of discharge for Storm drain C, Xeriscape garden, and Quarantine station are shown in figures 9, 10 and 11.

Samples were analyzed for all constituents listed in the Stormwater Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2005) except for FC and BOD.

Xeriscape garden.--A grab sample and a composite sample were created from the samples collected by the automatic sampler. The grab sample was created using water combined from the first seven bottles to represent the first flush. Water from the first two bottles were used for O+G and TPH analyses. Water from the next five bottles were combined

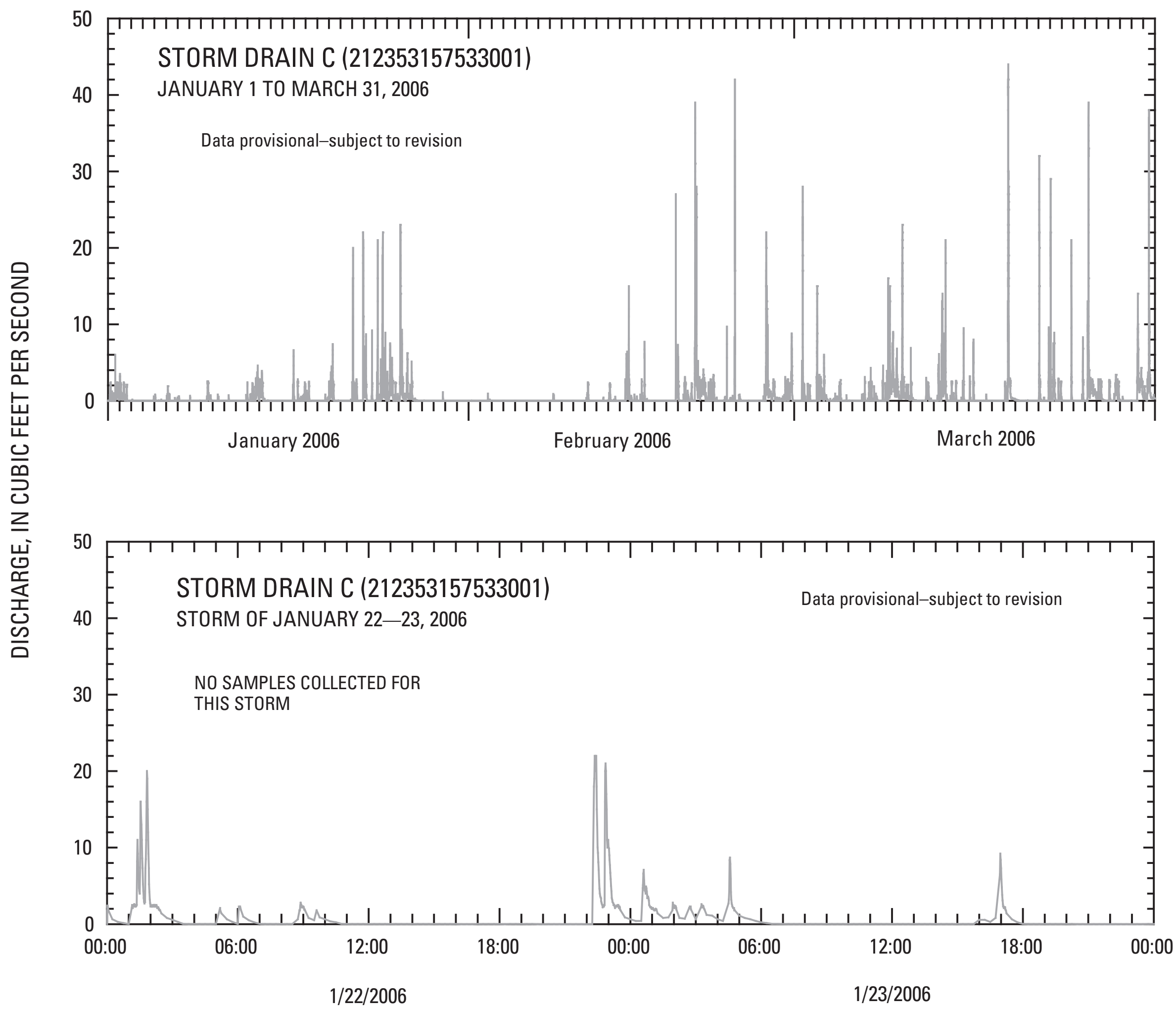

Figure 6. Discharge at Storm drain C (212353157533001) from January 1 to March 31, 2006; and detail of January 22—23, 2006, Oahu, Hawaii.

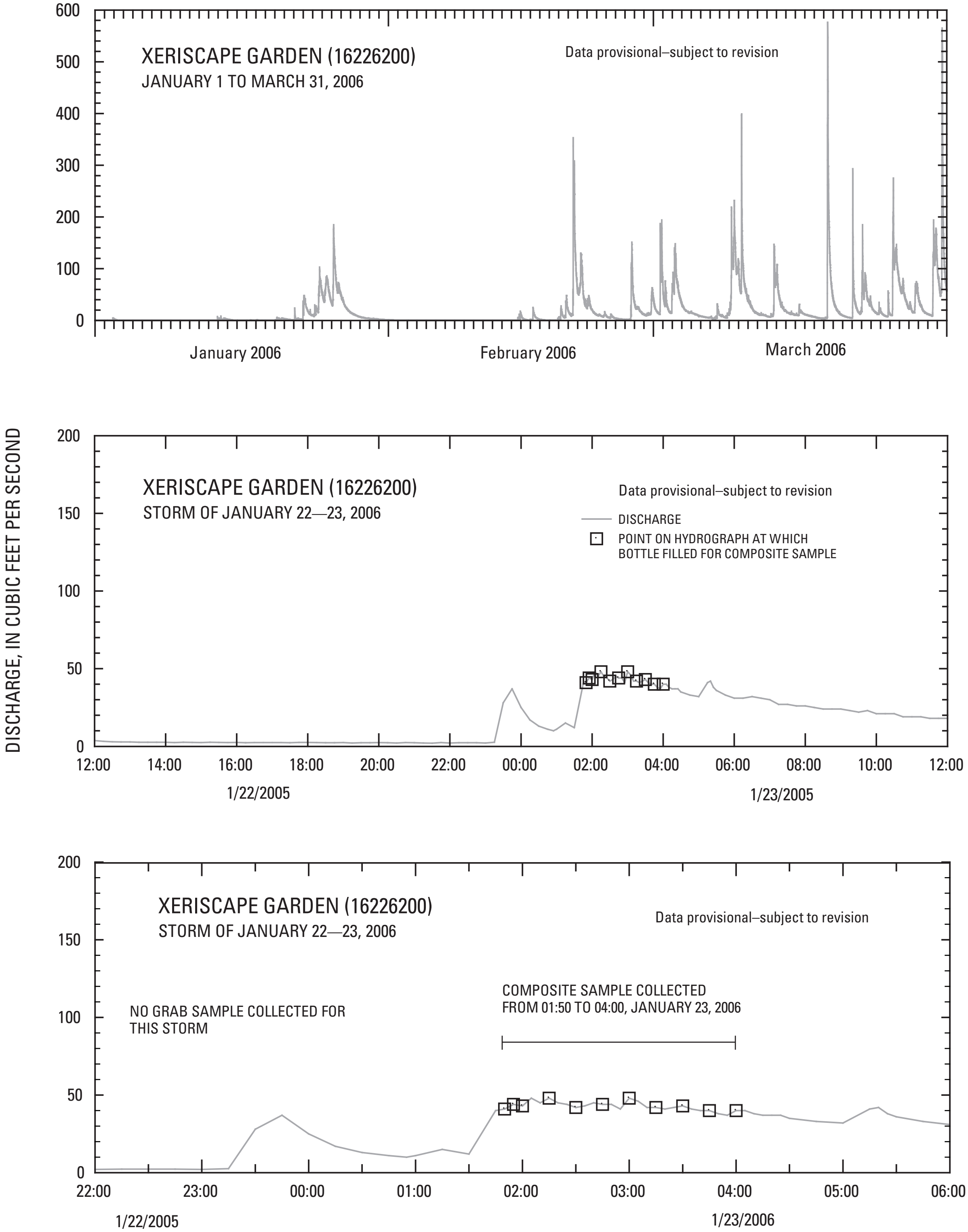

Figure 7. Stream discharge at Xeriscape garden (16226200) for January 1 to March 31, 2006; detail of January 22—23, 2006; and detail of 8-hour period from 22:00 January 22 to 06:00 January 23, 2006, Oahu, Hawaii.

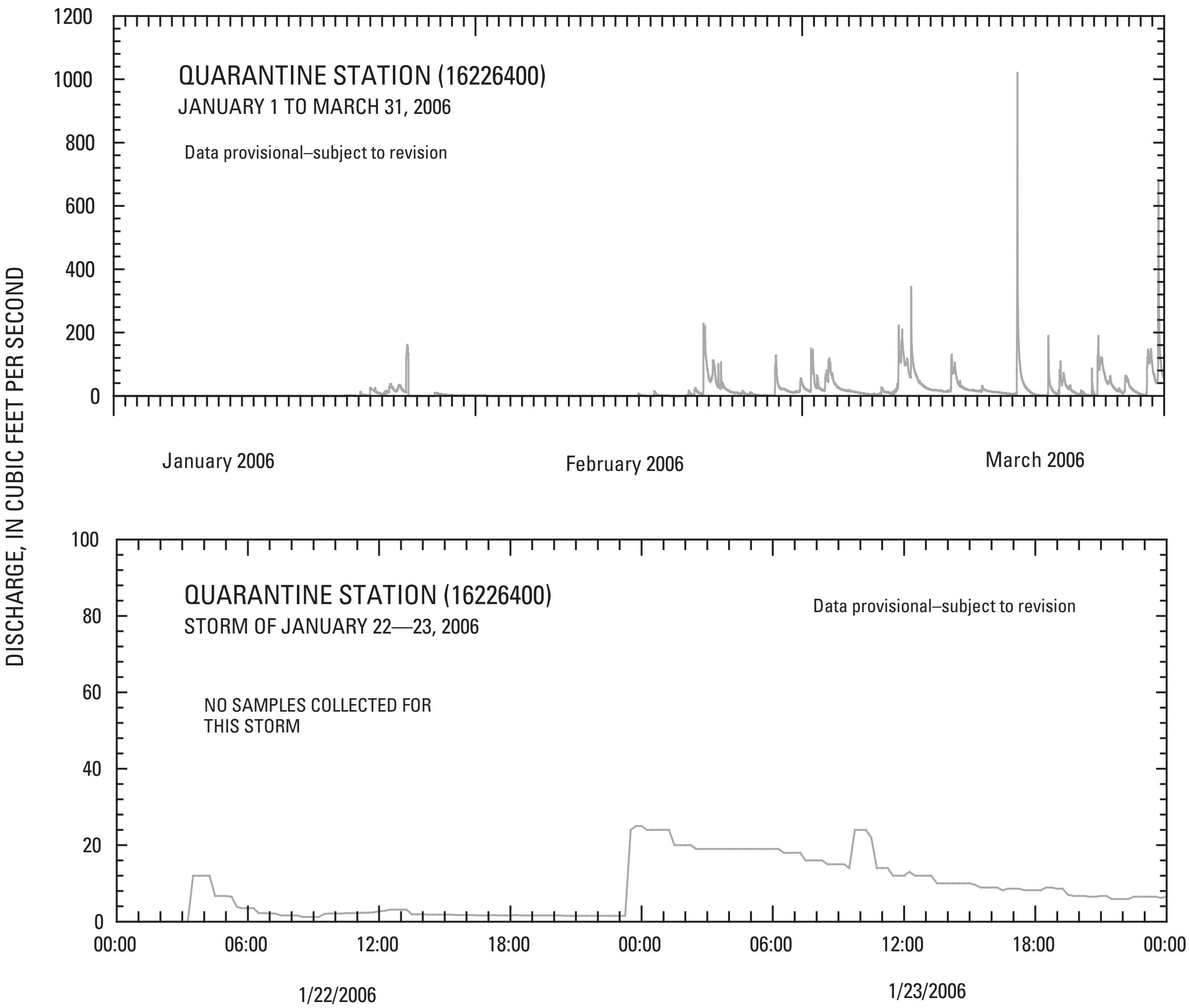

Figure 8. Stream discharge at Quarantine station (16226400) for January 1 to March 31, 2006; and detail of January 22—23, 2006, Oahu, Hawaii.

in a churn for the other analyses. The average discharge for the grab sample was 47 ft^3/s. The composite sample was created using water from bottles 8 through 24 from the automatic sampler. The average discharge for the composite sample was 213 ft^3/s. Peak discharge for the storm was 353 ft^3/s at 12:50 on February 20, 2006.

Quarantine station.--The automatic sampler filled 12 bottles during the storm. A composite sample was created using water from all 12 bottles from the automatic sampler. The average discharge for the composite sample was 158 ft^3/s. Peak discharge for the storm was 227 ft^3/s at 13:00 on February 20, 2006.

Storm of February 28—March 2, 2006

This storm was sampled over a three day period. The Xeriscape garden automatic sampler triggered first on February 28, 2006, during a period when discharge did not exceed 70 ft^3/s. The sampler at the Quarantine station was not triggered until March 1, 2006 during a period of greater discharge. The Storm drain C gage had multiple peaks during the three days. Samples from the automatic sampler, collected on March 1, 2006, were combined into a composite sample. Grab samples were collected on March 2, 2006. Hydrographs of discharge for Storm drain C, Xeriscape garden, and Quarantine station sites are shown in figures 12, 13, and 14, respectively.

Samples were analyzed for all constituents listed in the Stormwater Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2005).

Bridge 8.--A grab sample was collected at 10:48 on March 2, 2006. The sample was collected using the EWI method at 20 sampling points spaced 1 ft apart. The stream width was 21.1 ft. A discharge of 22.5 ft^3/s was measured immediately prior to sampling.

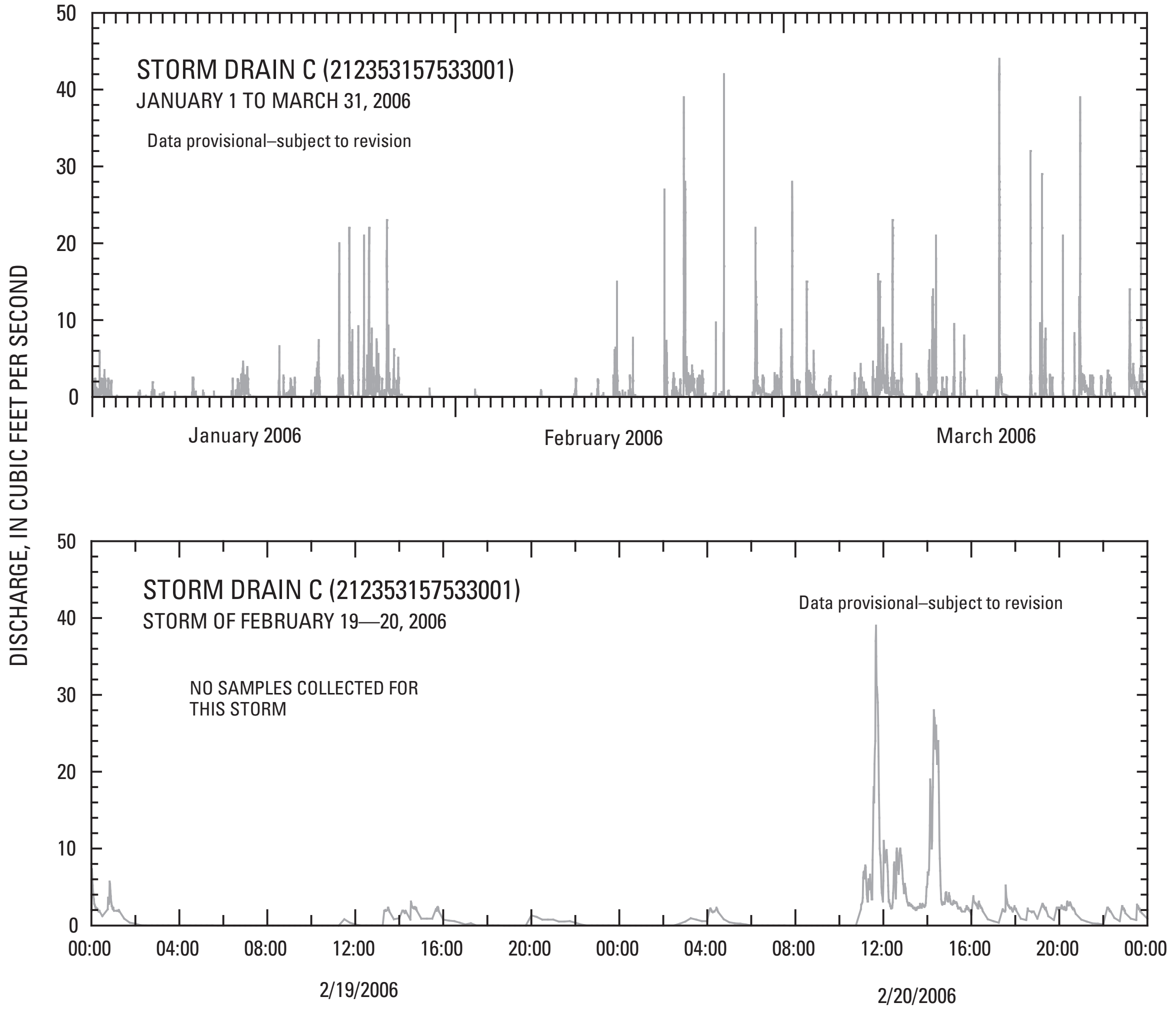

Figure 9. Discharge at Storm drain C (212353157533001) for January 1 to March 31, 2006; and detail of February 19—20, 2006, Oahu, Hawaii.

Storm drain C.--No grab sample was collected at Storm drain C, the flow was too low to sample when the sampling team arrived at the gage.

Three samples from the automatic sampler were collected between 16:52 and 17:31 on March 1, 2006. The volume of water from the three bottles was not sufficient to create a flow-weighted, time-composite sample. The entire contents of the 3 automatic samples were combined as a non-flow-weighted composite sample. The average discharge was 6.9 ft^3/s. Peak discharge for the storm was 28 ft^3/s at 17:34 on March 1, 2006.

Xeriscape garden.--A grab sample was collected on March 2, 2006. The stream width was 15.3 ft. The stream was sampled at 10 sampling points located on the right side (looking downstream) of the section. The left side of the section was too shallow to sample. A discharge of 19.1 ft^3/s was measured about an hour prior to the sampling.

A composite sample was created using water from all 24 bottles from the automatic sampler. The sample was collected between 19:11 and midnight on February 28, 2006. The sample was processed on March 2, 2006. The average flow for the composite sample was 52 ft^3/s. Peak discharge for the storm was 194 ft^3/s at 21:30 on March 1, 2006.

Quarantine station.--A grab sample was collected on March 2, 2006. The stream width at the time of sampling was 13.5 ft. The sample was collected using the EWI method. A discharge of 24.9 ft^3/s was measured about 50 minutes prior to sampling.

A flow-weighted composite sample was created using water from 23 bottles from the automatic sampler. The samples were collected between 18:04 and 23:06 on March 1, 2006, and were combined and processed on March 2, 2006. Average discharge for the sample was 113 ft^3/s. Peak discharge for the storm was 149 ft^3/s at 18:00 on March 1, 2006.

Stadium.--One grab sample was collected on March 2, 2006, using the EWI method at 3 sampling points distributed 1 ft apart along the right side of the channel. The flow was

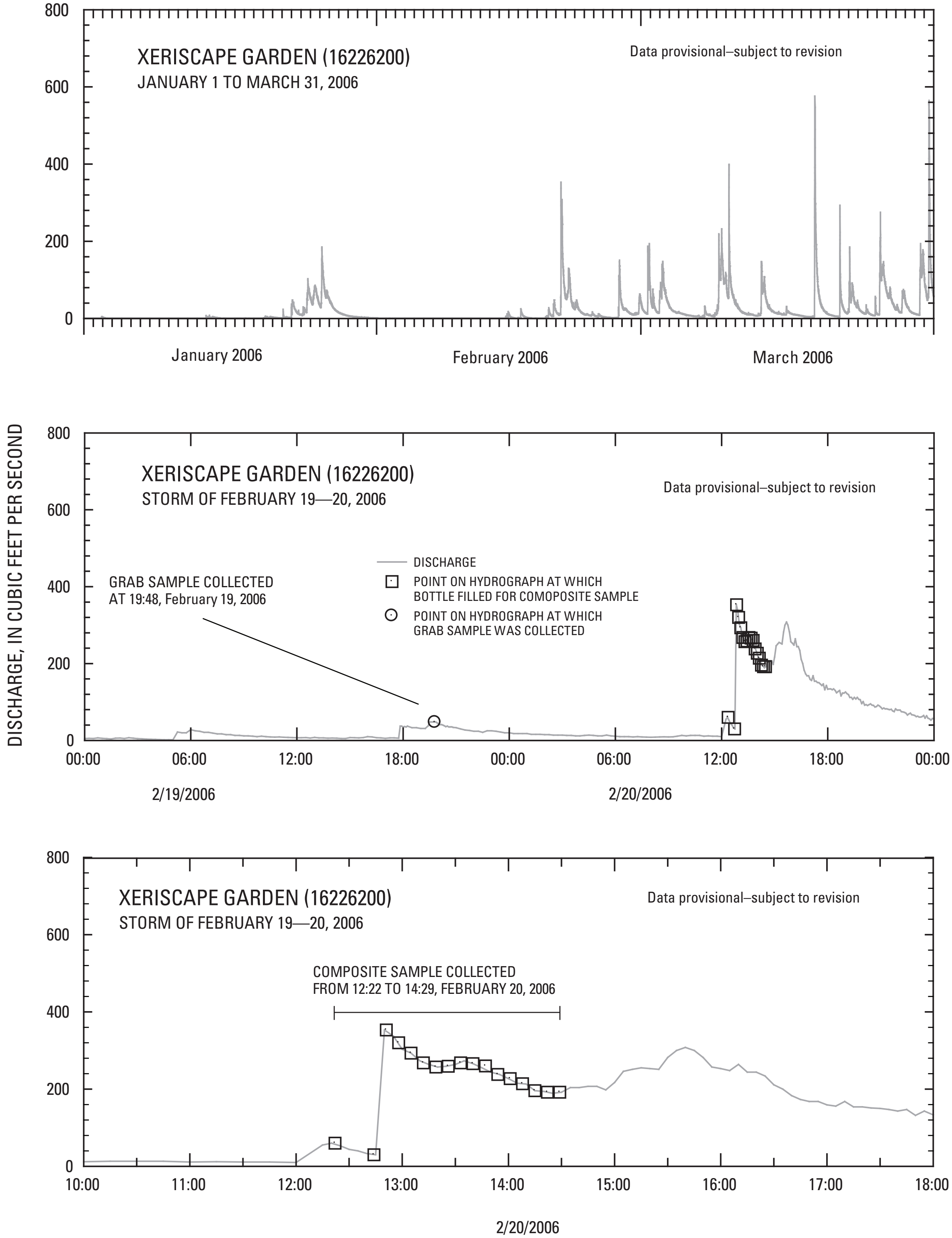

Figure 10. Stream discharge at Xeriscape garden (16226200) for January 1 to March 31, 2006; detail of February 19—20, 2006; and detail of 8-hour period from 10:00 to 18:00 on February 20, 2006, Oahu, Hawaii.

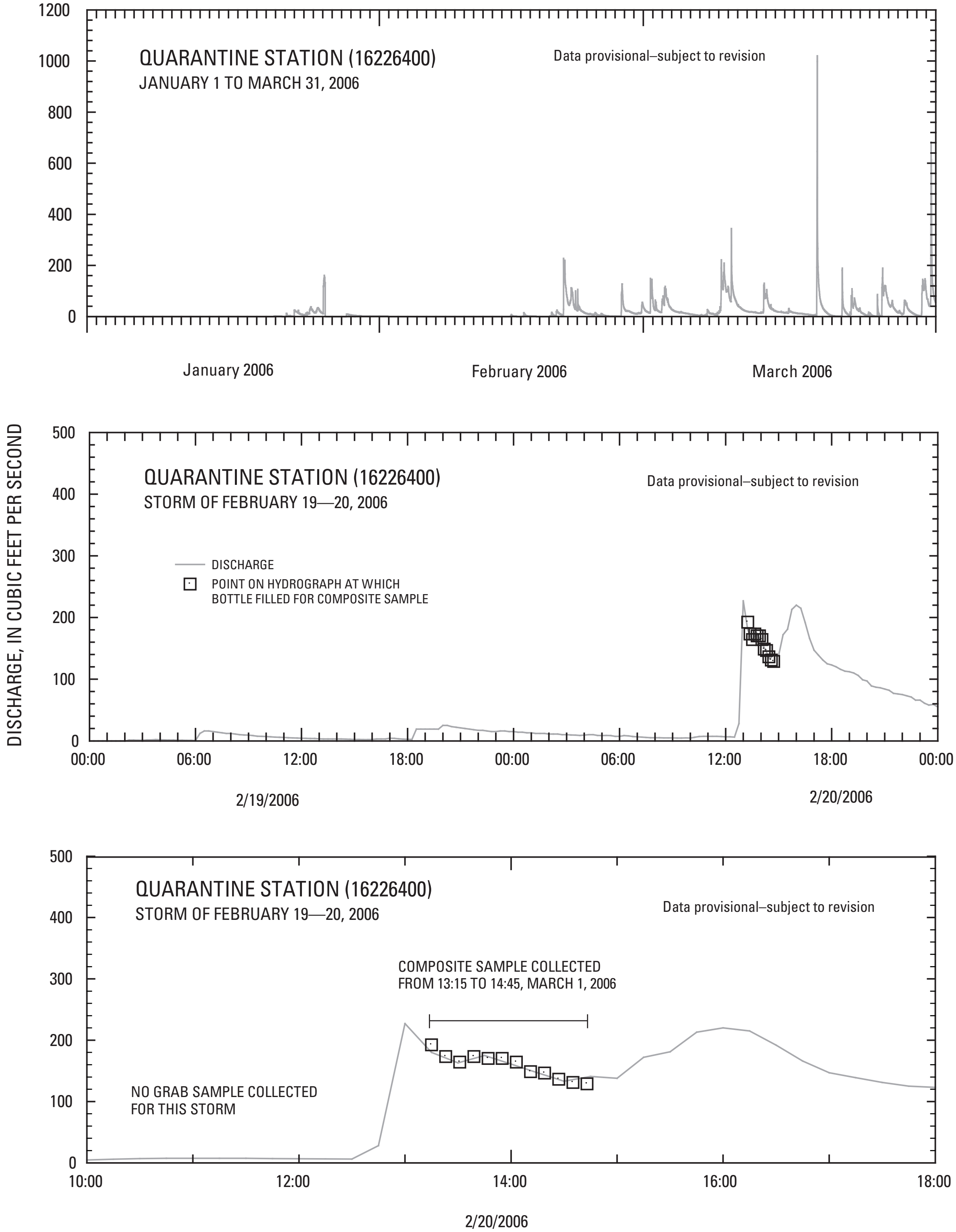

Figure 11. Stream discharge at Quarantine station (16226400) for January 1 to March 31, 2006; detail of February 19—20, 2006; and detail of 12-hour period from 10:00 to 22:00 on February 20, 2006, Oahu, Hawaii.

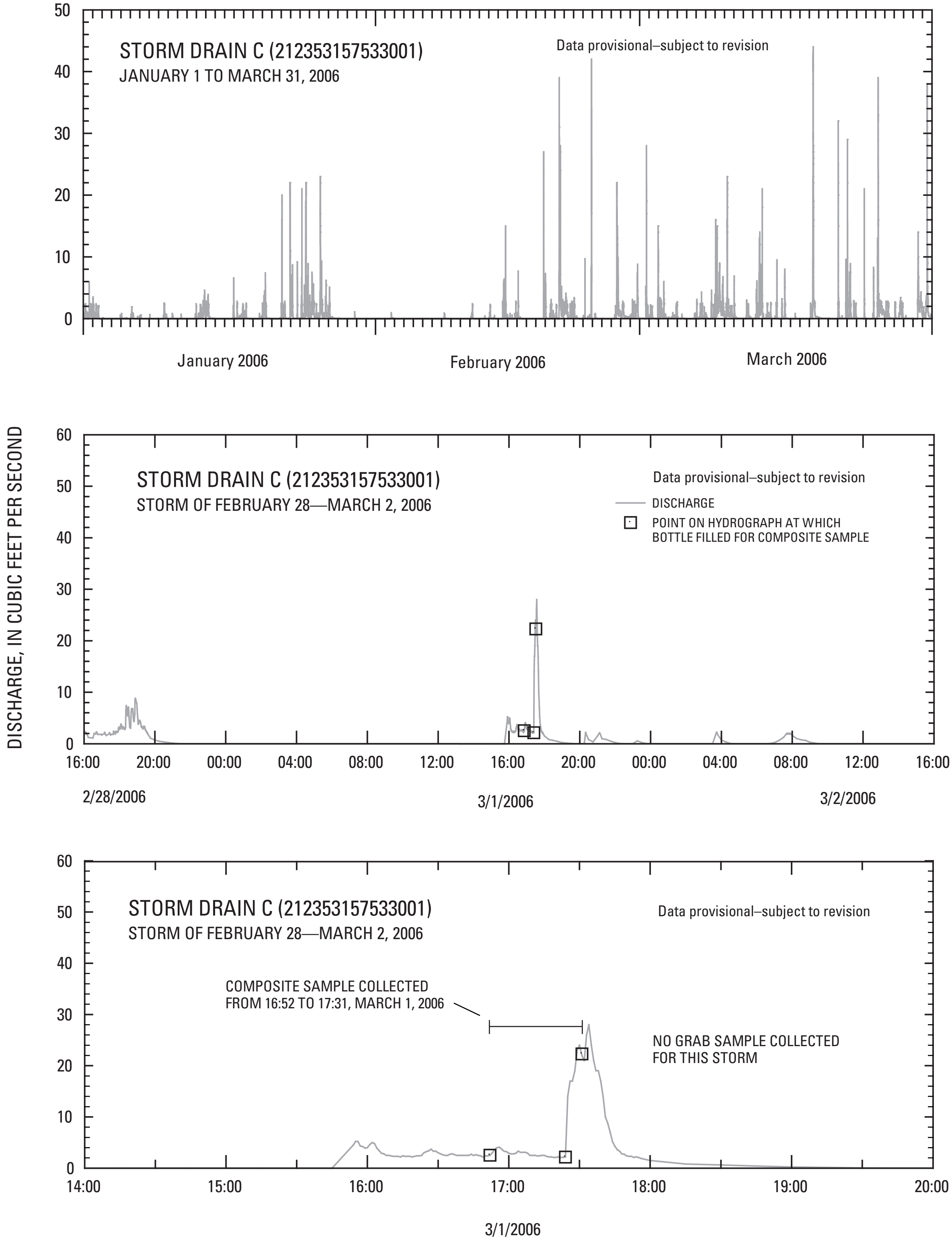

Figure 12. Discharge at Storm drain C (212353157533001) for January 1 to March 31, 2006; detail of February 28—March 1, 2006; and detail of 6-hour period from 14:00 to 20:00 on March 1, 2006, Oahu, Hawaii.

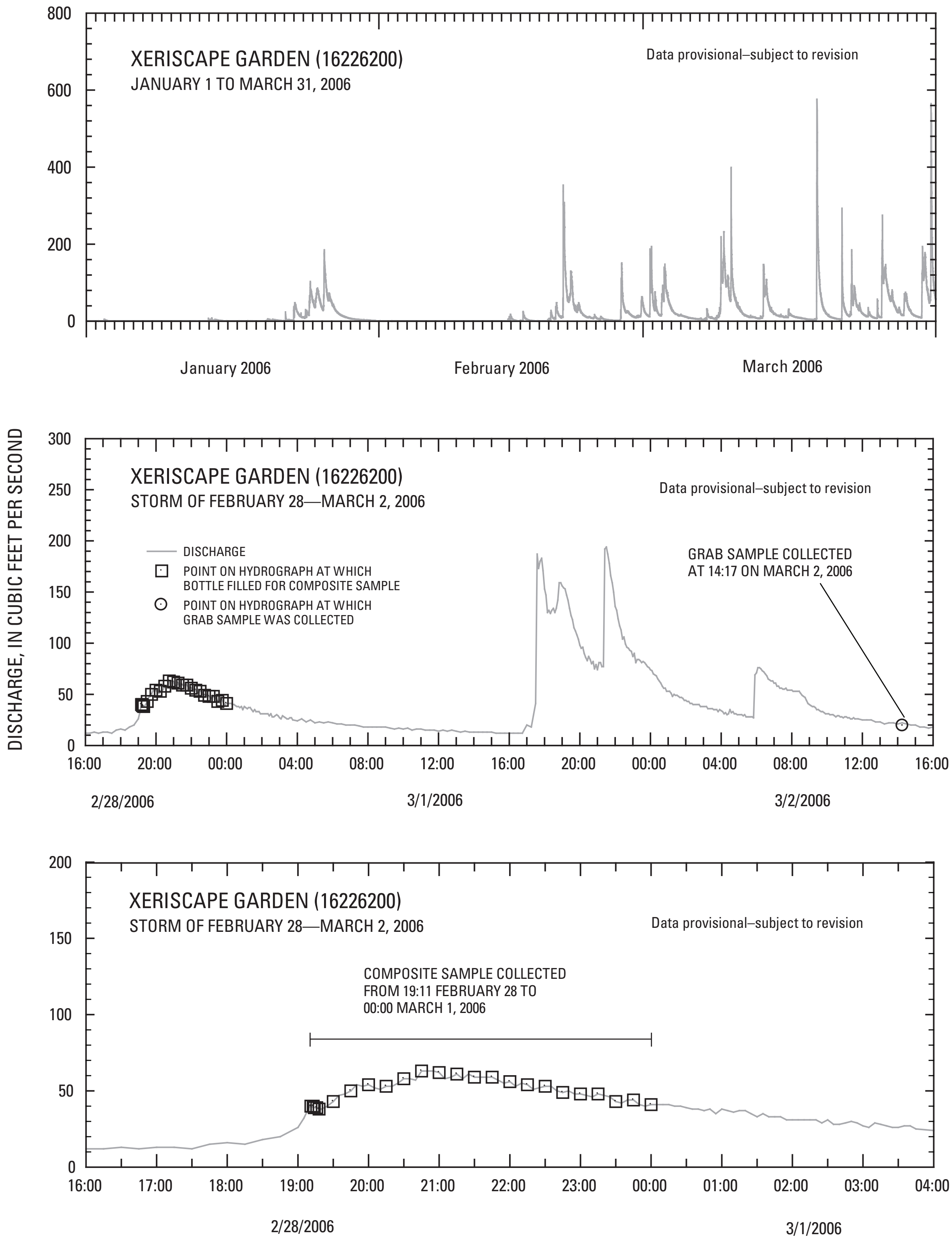

Figure 13. Stream discharge at Xeriscape garden (16226200) for January 1 to March 31, 2006; detail of February 28—March 2, 2006; and detail of 12-hour period from 16:00 February 28 to 04:00 March 1, 2006, Oahu, Hawaii.

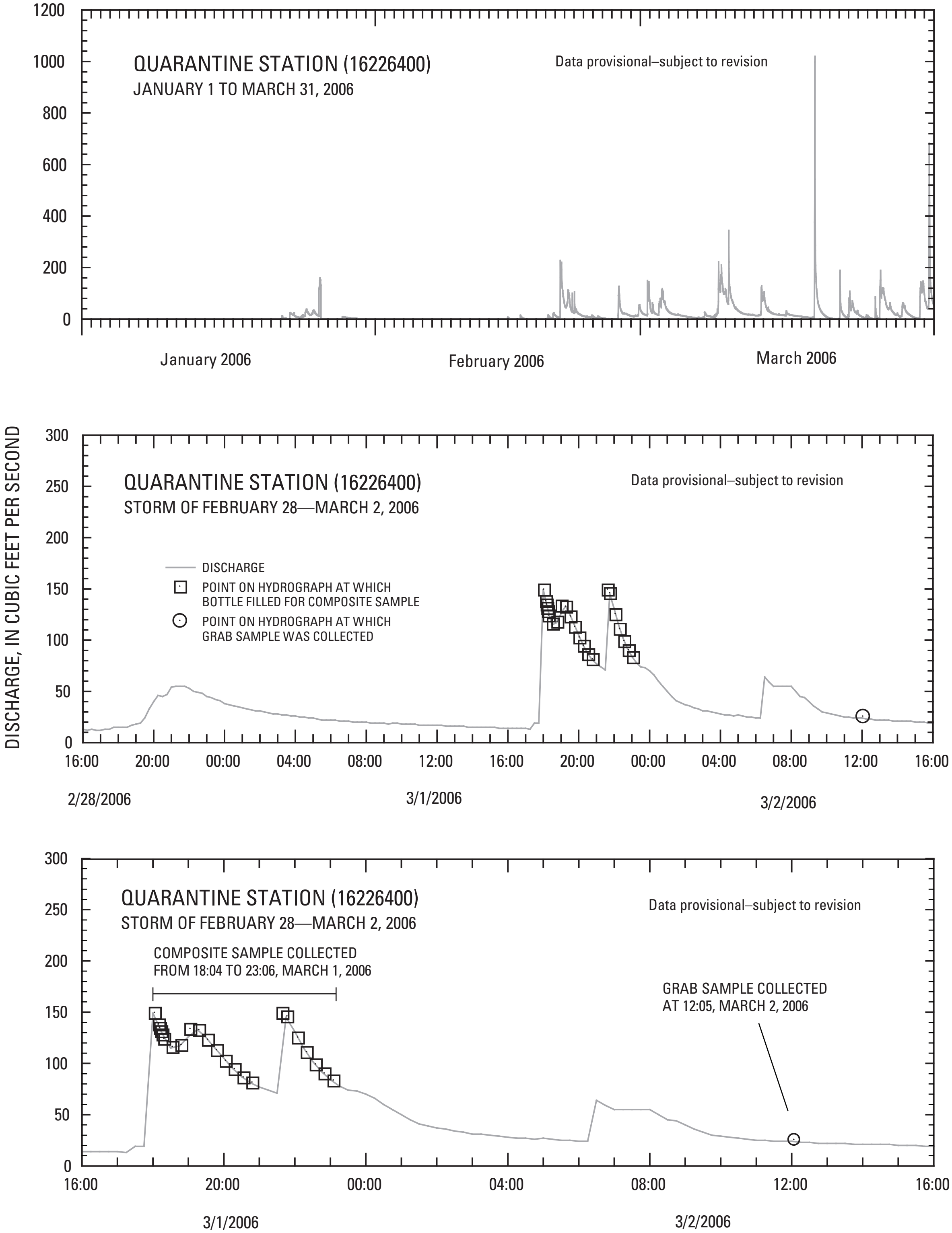

Figure 14. Stream discharge at Quarantine station (16226400) for January 1 to March 31, 2006; detail of February 28—March 2, 2006; and detail of 24-hour period from 16:00 March 1 to 16:00 March 2, 2006, Oahu, Hawaii.

too shallow in other areas to sample. Depths were too shallow to sample using the DH-81 sampler, therefore, a bottle was dipped at the three points and combined in the churn. A stream flow measurement was made about an hour prior to sampling using a flow meter. The discharge was 20.9 ft^3/s.

Second Quarter 2006 – April 1 to June 30, 2006

One storm was sampled during the second quarter 2006 on May 5.

Storm of May 5, 2006

Rainfall on May 5, 2006, provided enough runoff to potentially sample at all sites. However, two samples were not collected: a grab sample at Storm drain C due to low flow at the time of sampling, and a composite sample at Xeriscape garden due to an earlier storm triggering the sampler and filling all of the bottles. Samples were analyzed for all constituents listed in the Stormwater Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2005). Hydrographs of discharge at Storm drain C, Xeriscape garden, and Quarantine station for the period of April 1 to June 30, 2006 are shown in figures 15, 16 and 17, respectively.

Bridge 8.--A grab sample was collected using the EWI method. The stream channel was 17 ft wide, and water was sampled every foot along the cross section at 16 sampling points. Discharge was measured at 60.1 ft^3/s about 30 minutes prior to sampling. A field duplicate was also collected at this site.

Storm drain C.--Seven samples from the automatic sampler were collected and used for a flow-weighted, time-composite sample. Average discharge for the composite sample was 13 ft^3/s. Flow was too low to collect a grab sample at the time of arrival at the site. Peak discharge for this storm was 25 ft^3/s at 03:52 on May 5, 2006.

Xeriscape garden.--A grab sample was collected using the EWI method. The stream channel was 28 ft wide, and water was sampled every foot at 21 sampling points. One sampling point near the right bank and 5 sampling points near the left bank were too shallow to sample. A discharge of 28.4 ft^3/s was measured concurrently with the sampling. Peak discharge for this storm was 202 ft^3/s at 07:55 on May 5, 2006.

The automatic sampler triggered and collected samples during a previous storm on April 29, 2006. Personnel were not able to clean and prepare the sampler prior to the May 5 storm, thus no composite sample was collected.

Quarantine station.--A grab sample was collected using the EWI method at 13 sampling points distributed every foot across the stream. The stream width was about 14 ft. A discharge of 40.8 ft^3/s was measured using a current meter about 1 hour prior to the sample collection, however, the discharge was falling during the time of sampling. A better estimate of discharge of 34 ft^3/s for the sample was determined from the stage at the time of sample collection and the rating. The peak discharge at this site was 138 ft^3/s at 08:00 on May 5, 2006.

A composite sample was created using the samples from the automatic sampler. Twelve bottles were filled between 09:47 and 11:40 on May 5, 2006. Average discharge for the composite sample was 63 ft^3/s.

Stadium.--The channel width was about 55 ft at the time of sampling. One grab sample was collected using the EWI method at 54 sampling points distributed every foot across the stream channel. A discharge of 61.2 ft^3/s was measured using a current meter immediately following the collection of the sample.

Quality Assurance

Field and laboratory quality-assurance procedures were implemented as described in the DOT Storm Water Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2005). Five quality-assurance samples were collected: three field-duplicate samples were collected concurrently with storm samples during three of the five of the storms, and two inorganic-blank-water (IBW) samples were collected between storms after routine cleaning of the sampling equipment. Results are not published in this report, but are available from the USGS Pacific Islands Water Science Center upon request.

All grab-sample-collection equipment was cleaned prior to use. The automatic-sampler intake lines were cleaned three times during the year at Storm drain C, four times at Xeriscape garden, and three times at Quarantine station. Due to the pattern of discharge in Storm drain C, the sampler was triggered occasionally and samples were collected during brief rain showers. The intake line at Storm drain C was potentially contaminated in this manner prior to storm sampling on July 12, 2005, February 28—March 2, 2006, and May 5, 2006. The potential for contamination is minimized because the automatic sampler conducts a rinse cycle prior to every sample collected. The rinse cycle routine is as follows: (1) sample line is first purged by air, (2) water is pumped up the line to a sensor located before the pump, (3) water is purged out, and (4) the sample is then collected. Thus, the rinse cycle reduces possible contamination from water pumped during earlier storms and from previously pumped samples during the same storm, and conditions the intake lines with sample water prior to collection.

IBW field-blank samples from the automatic samplers were collected at Quarantine station on December 29, 2005 and May 17, 2006. Intake lines were cleaned prior to the collection of IBW field-blank samples. These field-blank samples were analyzed for inorganic constituents only, which consisted of nutrients, cadmium, copper, lead, chromium, nickel, and zinc. Results are not published in this report, but

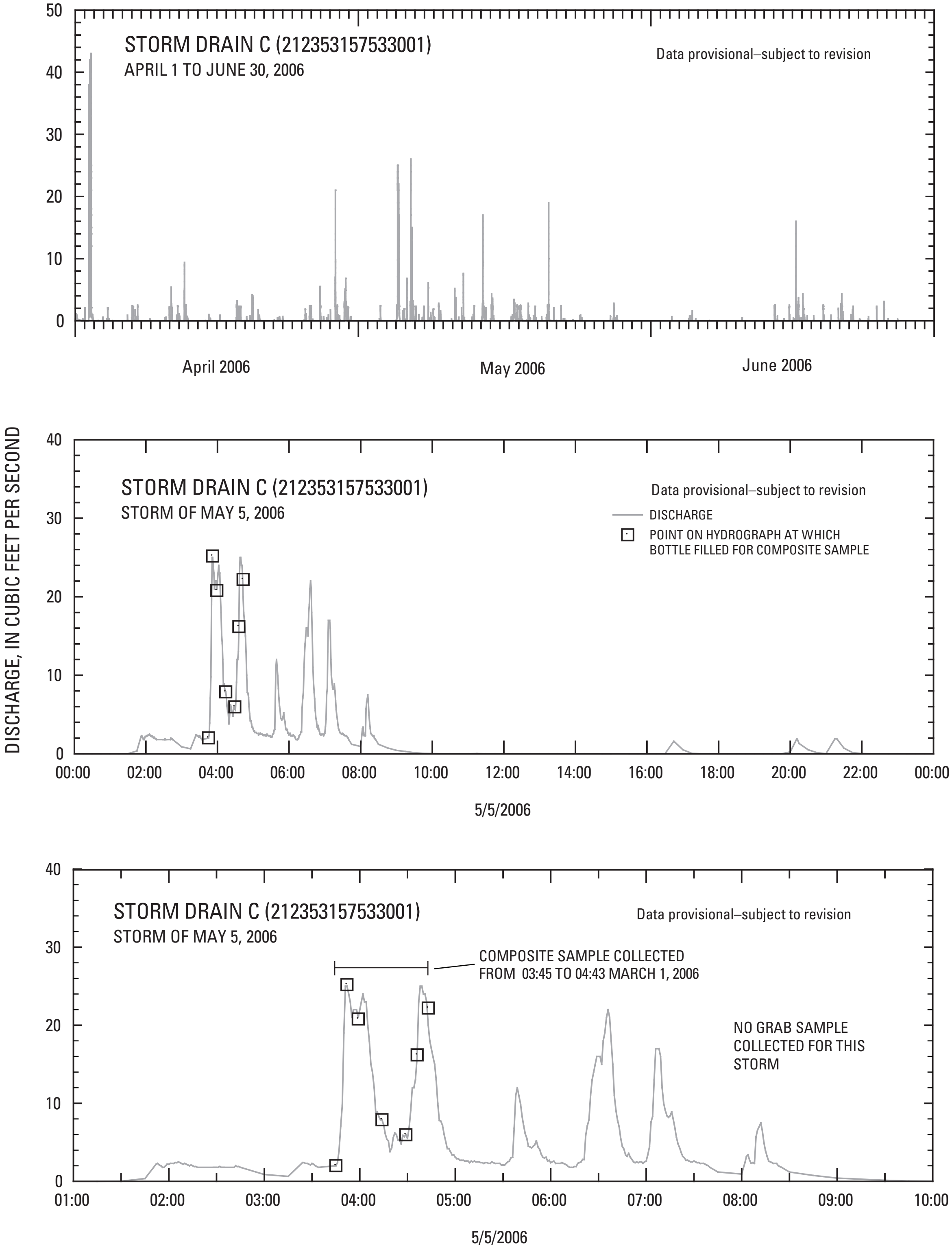

Figure 15. Discharge at Storm drain C (212353157533001) for April 1 to June 30, 2006; detail of May 5, 2006; and detail of 9-hour period from 01:00 to 10:00 on May 5, 2006, Oahu, Hawaii.

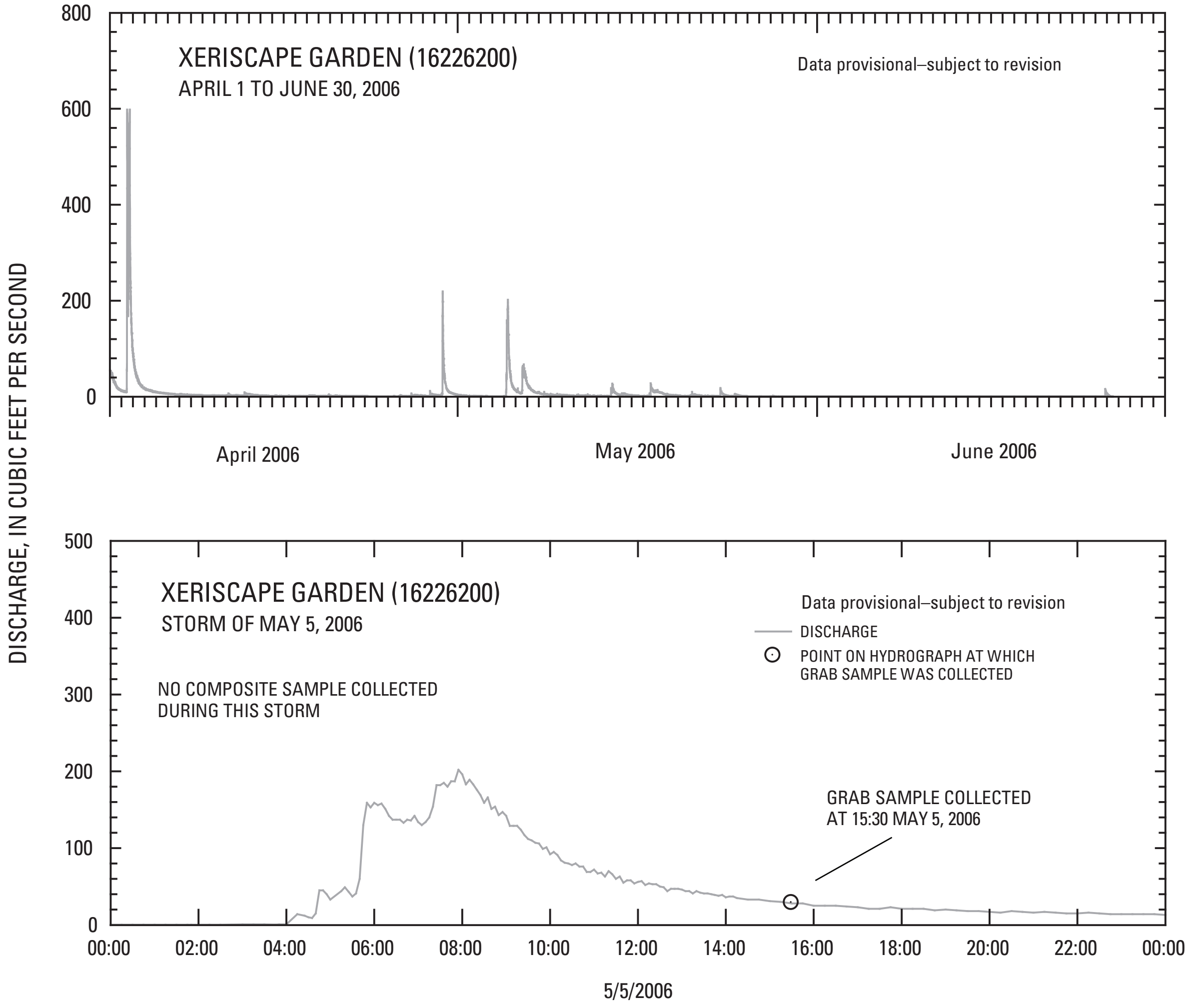

Figure 16. Stream discharge at Xeriscape garden (16226200) for April 1 to June 30, 2006; and detail of May 5, 2006, Oahu, Hawaii.

are available from the USGS Pacific Islands Water Science Center upon request.

Inorganic constituents were detected at levels at or below the minimum reporting levels for most constituents, which are listed in Table 1. Copper and zinc were detected in the field blank collected on December 29, 2005 at concentrations slightly above the minimum reporting levels, and ammonia + organic nitrogen was detected in the field blank collected on May 17, 2006 at a concentration slightly above the minimum reporting level.

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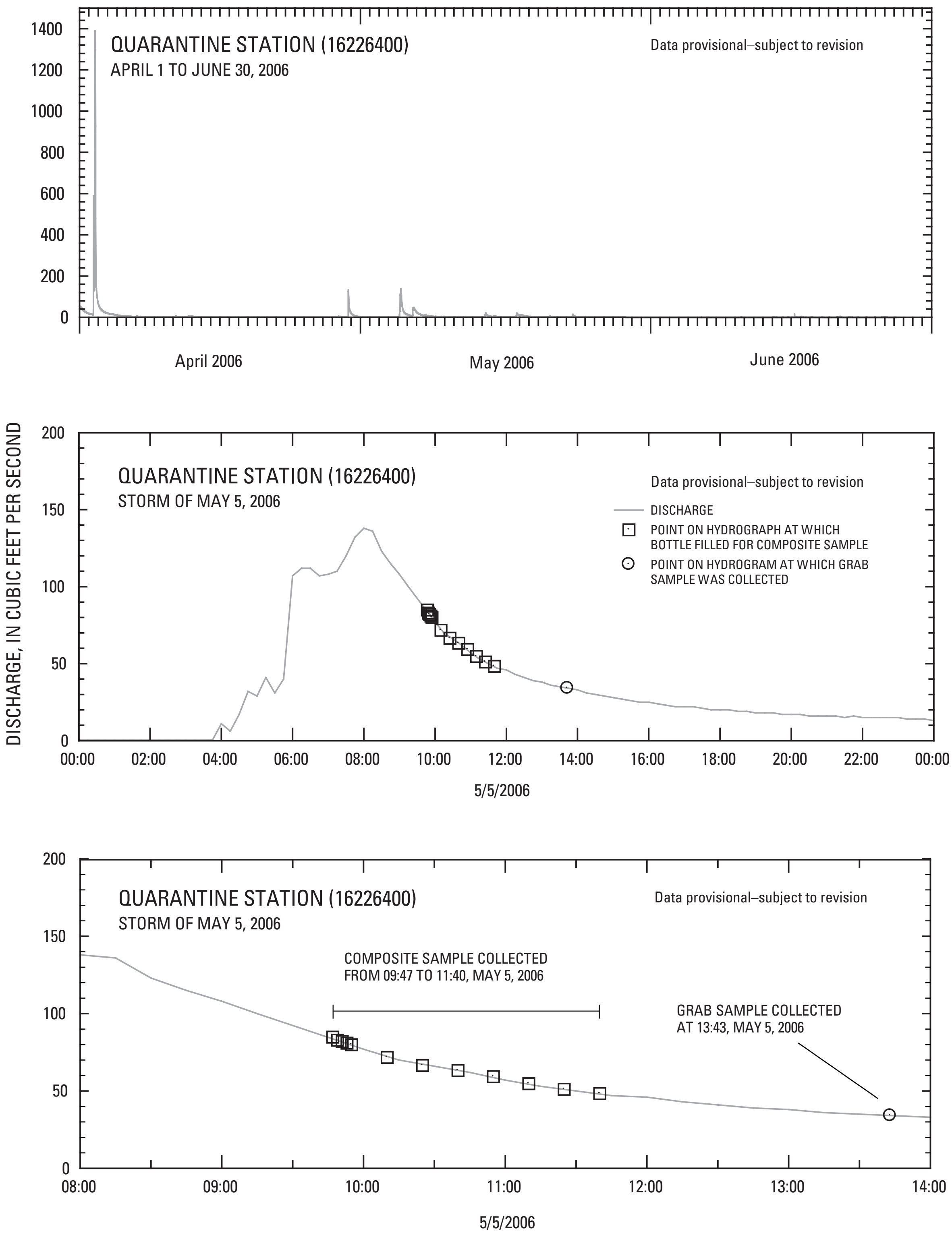

Figure 17. Stream discharge at Quarantine Station (16226400) for April 1 to June 30, 2006; detail of May 5, 2006; and detail of 6-hour period from 08:00 to 14:00 on May 5, 2006, Oahu, Hawaii.

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Appendix A: Discharge-Reporting and Load-Calculation Methods

This appendix further defines the methods used for reporting discharge data and constituent-concentration data and the methods for calculating constituent loads. Discharge and water-quality data values are rounded off to the number of significant figures that best describe the precision of the measurement.

Discharge data.--Table 2 shows the number of significant figures and rounding limits for the range of discharges used in this study. Discharges measured by current meter or float-measurement techniques follow guidelines for measured discharges. Discharges determined by streamflow rating or by averaging follow guidelines for daily mean discharges (Sauer, 2002). Measured discharges may have more significant figures because they are considered more precise than averaged discharges.

Table 2. Significant figures and rounding limits for measured, streamflow-rating, and averaged discharges

[ft^3/s, cubic feet per second; <, actual value is less than shown; , actual value is greater than or equal to value shown]

Range of discharge (ft^3/s)	Measured discharge		Streamflow-rating and averaged discharges	
	Significant figures	Rounding limit	Significant figures	Rounding limit
<0.10	2	thousandths	1	hundredths
≥0.10 and <1.0	2	hundredths	2	hundredths
≥1.0 and < 10	3	hundredths	2	tenths
≥10 and < 100	3	tenths	2	units
≥100	3	variable	3	variable

Calculation of loads.--Table 3 shows the conversion factors used for determining constituent loads. Constituent loads for all analyses are reported as pounds per day (lbs/day) except for fecal coliform, which is reported as billion colonies per day. All loads are the product of constituent concentration multiplied by associated discharge and the appropriate conversion factor (equation 1). Concentrations are reported in milligrams per liter (mg/L) or micrograms per liter (µg/L), except for fecal coliform, which is reported in most probable number (of colonies) per 100 milliliters (MPN/100 ml). Four significant figures are used for the conversion factors; however, the load value is reported with the lesser number of significant figures of the values of concentration and discharge.

$$Q\,(\,C\,)\,K = L \tag{1}$$

Where
Q = discharge (ft^3/s)
C = constituent concentration (mg/L, µg/L, or MPN/100ml)
K = conversion factor
L = constituent load (lbs/day or billion colonies per day)

Table 3. Conversion factors for computing daily loads from constituent concentration and discharge

[mg/L, milligrams per liter; µg/L, micrograms per liter; MPN/100mL, most probable number (of colonies) per 100 milliliters; lbs/day, pounds per day]

Unit of concentration	Conversion factor[a]	Load unit
mg/L	5.394	lbs/day
µg/L	0.005394	lbs/day
MPN/100mL	0.02447	billion colonies per day

[a]All conversion factors are based on discharge in cubic feet per second.

Appendix B: Physical Properties, Concentrations, and Loads for All Samples Collected from Halawa Stream Drainage Basin During the Period from July 1, 2005 to June 30, 2006, Oahu, Hawaii – Provided as an Excel file